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# FOREST PEST MANAGEMENT

United States
Department of
Agriculture

Forest Service

Forest Pest Management
Denver, Colorado

# FOREST HEALTH MONITORING PLAN FOR COLORADO

by

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TABLE OF CONTENTS


| | Page |
|---|---|
| TABLE OF CONTENTS | i |
| INTRODUCTION | 1 |
| PROGRAM DESIGN | 2 |
| Detection Monitoring | 2 |
| Evaluation Monitoring | 2 |
| Intensive-Site Ecosystem Monitoring | 2 |
| SAMPLING DESIGN | 2 |
| PROGRAM COOPERATION AND COORDINATION | 3 |
| Coordination within the Forest Service | 3 |
| Coordination with States | 3 |
| PROGRAM OBJECTIVES FOR FOREST PEST MANAGEMENT | 4 |
| FHM Responsibilities - National Program | 4 |
| FHM Responsibilities - State of Colorado | 5 |
| LOGISTICAL PREPARATIONS | 6 |
| QUALITY CONTROL/QUALITY ASSURANCE | 6 |
| FIELD METHODS GUIDES | 7 |
| DATA ANALYSIS | 7 |
| Forest Service Role in Analysis | 7 |
| EPA Role in Analysis | 7 |
| IMPLEMENTATION SCHEDULE | 8 |
| FUNDING NEEDS | 8 |
| INDICATORS OF FOREST HEALTH | 9 |
| REFERENCES | 10 |
| APPENDICES | |
| A Colorado Forest Health Monitoring Program Schedule | 11 |
| B Listing of Analysis Table Titles | 12 |
| C Summary of Anticipated Expenses | 14 |
| D Listing of FHM Plot Locations for 1992 | 15 |
| E Summary of Western U.S. Indicators and Data Items for Forest Health Monitoring | 16 |
| F Damage and Mortality Assessment (FHM Methods Guide) | 18 |
| FIGURES | |
| 1 Map of Colorado With Hexagon Locations | |
| 2 Current FHM/EMAP Field Plot Design | |
| 3 FHM Plot Design (Detail) | |
| 4 Plot Form - FHM Western Mortality, Full Hectare Plot | |

## INTRODUCTION

The Public's concern for the health and productivity of the nation's forests has prompted passage of federal legislation authorizing surveys to monitor long term trends in the health of forest ecosystems. Monitoring forest health is an integral part of the USDA Forest Service's Forest/Atmosphere Interaction Program proposed under the Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (PL 100-521). This act authorizes a 10-year program of research and monitoring to better understand the relationships between forest health and air pollutants, and recognizes the need for long-term monitoring. In addition, the Farm Bill of 1990 (PL 101-624) encouraged the Forest Service to work in partnership with the state foresters or state agencies to monitor forest health. The result of this legislation is the current implementation of a National Forest Health Monitoring Program (NFHMP) to determine and annually report on the condition of the nation's forests.

Congress has provided the Forest Service, through the Secretary of Agriculture, authority, direction, and funding to establish a national forest health monitoring program. Amendments to the Cooperative Forestry Assistance Act of 1978 (PL 95-313) are significant to this activity because forest health monitoring is explicitly authorized. Section 5 of PL 95-313, Insect and Disease Control, is re-designated Section 8, Forest Health Protection. Section 8(b) directs that surveys be conducted to detect and appraise insect infestations and disease conditions and man-made stresses affecting trees. It also directs the establishment of a monitoring system throughout the forests of the United States to determine detrimental changes or improvements that occur over time, and report annually concerning such surveys and monitoring.

Currently the USDA Forest Service gathers data on forest resources and forest pests in several ways. Periodic resource surveys are conducted by the Forest Inventory and Assessment (FIA) groups on most forested lands. Insect and disease surveys are conducted on federal lands by Forest Health Management (FHM) and in cooperation with state forestry agencies on state and private lands.

The NFHMP is a cooperative venture with the U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP); state forestry agencies; FIA; FHM; Forest Service Experiment Stations; and National Forests. The NFHMP utilizes the expertise of all these groups to collect, archive, analyze, interpret, and report forest conditions. The initial objective is to develop a baseline on the health and condition of forests with permanent plots and forest damage surveys in every state. This baseline information will be used yearly to monitor forest health, detect changes, evaluate the causes of those changes, and to direct research to explain those changes.

In summary, Forest Health Monitoring is intended to be a long-term effort with a major emphasis to describe existing conditions and to detect new problems and unexpected changes from established baseline forest conditions.

## PROGRAM DESIGN

Although Forest Service Research, through the NFHM Program Manager, has the overall lead for NFHM design, implementation, and reporting, FHM and participating states have direct responsibility for designing and implementing the FHM/state components of NFHM.

The NFHM Program is a three-tiered, long-term process to provide regional (multi-state) and national information on forest health status and trends. Each successive tier requires progressively more detailed information. The tiers are:

**Detection Monitoring** -- to detect deviation of key monitoring elements from established baseline conditions or trends. This is the first and most extensive level. FHM and Research share responsibility for this tier which consists of (1) a plot component (Research) -- a geographically-based network of permanent plots distributed throughout the nation's forested areas, and (2) a survey component (FHM) -- forest damage surveys and reports of forest pest effects. Detection Monitoring is designed to discover and describe changes in forest health conditions.

**Evaluation Monitoring** -- to determine extent, severity, cause, and management responses beyond that done in Detection Monitoring. This is the second level, is FHM's responsibility to initiate, and is activated by Detection Monitoring results. Evaluation Monitoring is designed to determine causes for changes in forest health status.

**Intensive-Site, Ecosystem Monitoring** -- to define basic relationships sufficient to predict consequences. This is the third level and provides the most detailed, long-term data for ecosystem research to determine causal relationships, predict rates of change in forest conditions, and identify management responses. FHM has little or no responsibility in Intensive-Site, Ecosystem Monitoring.

## SAMPLING DESIGN

The national EMAP sample design that was adopted for the FHM program was developed by a team of statisticians with provision for considerable flexibility in implementation of the design. It is based on a grid of 160,000 acre hexagons laid over the contiguous U.S., with plots systematically offset from the hexagon centroids that are about 27 kilometers apart. It requires about 12,500 of these hexagons to cover the contiguous U.S. It is estimated that about 4,000 of the hexagons will fall on forest ecosystems. Colorado has about 150 hexagon sites within its boundaries that are on forested sites (Figure 1). It is planned that about 40 of the plots will be visited each year for 4 years. The blackened hexagons represent those plots that will be visited in 1992 (Figure 1).

At each of the centroid offset plots, a 40 square kilometer mini-hexagon is evaluated, wherein landscape characterization is performed using remote sensing media (thematic mapping classification). Within that hexagon, type maps are compiled on vegetation type and land use.

Finally at the centroid of all the hexagons that are classified as forest ecosystem, a ground plot is established over a 1-hectare area. Four sample sub-points are placed equidistant over the 1-hectare area (see Figure 2), and at these sub-points (see Figure 3), a suite of forest health indicators is measured to detect changes in the ecosystem.

## PROGRAM COOPERATION AND COORDINATION

### Coordination within the Forest Service

The NFHMP is designed to build on existing Forest Service programs. The FS Staff units most involved have been Forest Fire and Atmospheric Sciences Research; Forest Inventory Assessment, Economics, and Recreation Research; Forest Health Management; Timber Management; and Watershed and Air Management.

FS Research, through the NFHM Program Manager, has the lead for NFHM design, implementation, and reporting. FHM has direct responsibility for providing pest conditions information in Detection Monitoring and for initiating Evaluation Monitoring activities. Both Detection and Evaluation Monitoring activities conducted by FHM will be coordinated with the NFHM Program. Forest Health Monitoring program and budget planning are coordinated among participating FS staff units.

As technical staff to National Forest System (NFS) resource managers, Regional and Area FHM staff will have an important role in planning Regional execution of the NFHM Program. Regional and Area FHM staff also have the responsibility for implementing the Regional FHM component of NFHM on NFS and other federal lands.

### Coordination with States

State cooperators will be fully involved with all phases of NFHM Program planning and execution. Regional and Area FHM staff will work with the Research Stations and the NFHM Program Manager to establish appropriate mechanisms for the State involvement essential for NFHM Program success and the establishment of plots on state and private lands.

**PROGRAM OBJECTIVES FOR FOREST HEALTH MANAGEMENT (FHM R-2)**

The objective for the FHM portion of the program is to discover if there are large scale episodes of forest pests and other stress or effects that are not related to historical or normal cycles of forest growth, decline, and stressor activities. This includes effects from (1) known agents; (2) changed activity of known agents; (3) new agents; and (4) unknown agents.

**FHM Responsibilities - National Program**

Detection Monitoring, On-Plot Activities:

The role of FHM involves the training of field crews or providing the necessary expertise to assess insect and disease damage on the plot and to conduct followup site visits with field crews while they are collecting information.

Detection Monitoring, Off-Plot Activities:

Standards for this activity are still under development for the western United States. In many cases, annual or periodic surveys are already conducted for many damages/pests; however, standardization is lacking. To establish a baseline and determine changes in forest conditions/health requires maintenance of information in a format that is readily retrievable with annual updates. Spatial mapping or Geographic Information System (GIS) is needed. FHM will be responsible for providing information on damage/pests in the vicinity of the forest health plots as well as the general forest area to explain changes that may result in forest health from these agents.

Evaluation Monitoring:

This level of monitoring will involve the design and implementation of intensive surveys to evaluate a detected or unexplained change in forest condition. FHM will provide leadership and technical support in this area. This could include additional surveys, site- or area specific evaluations, more detailed monitoring, and assist research with specific studies.

Intensive Site-Ecosystem Monitoring:

This is strictly a research responsibility. FHM will have little or no involvement in this phase.

Reporting and Interpretation of Results:

FHM responsibilities for reporting include the interpretation of specific information on the detection plot network (insect and disease occurrence, weather damage, air-pollution bio-indicators). The off-plot detection information will be the major aspect of FHM activity, including the development of regional damage/pest information which will be collected and organized into a data base for

GIS applications. Both of these information sets and activities will be combined into annual regional and national reports on forest health monitoring which are being organized by FS Research.

In addition, the off-plot detection information along with other sources of data on forest conditions will be used in the development of annual state health reports. These reports will be developed by the cooperating state agencies with assistance from FHM.

Evaluation monitoring reports will be developed as needed and vary depending on the focus of the evaluation project. This information may also be used to support observations and conclusions contained in annual detection monitoring reports.

**FHM Responsibilities - State of Colorado**

The emphasis of the program in Colorado in FY 92 will be to begin implementation of detection level monitoring on the forest health plots and in the vicinity of the plots to obtain baseline information on forest pests/damage. The Colorado State Forest Service (CSFS) will be fully involved with all phases of the program planning and execution. FHM R-2 staff will also work with the Western Coordinator for Forest Health Monitoring (RMS) and FIA (INT) units responsible for plot installation.

The objective is to find and document change in large-scale forest damage, location, extent, severity, duration, frequency and cause. FHM is also responsible for conducting supplemental plot visits and surveys where needed to evaluate causes of forest health change. Reporting elements include damage, location, hosts, pests, scope, severity, date and land ownership.

FHM R-2 will provide a full-time Forest Health Monitoring coordinator to accomplish the necessary coordination between the various agencies involved, to hire field crews and provide training, to conduct field reviews, to analyze and interpret data, and compile reports. In subsequent years, as additional states within the Rocky Mountain Region are included in the NFHMP, the coordinator would provide continuing support and continuity to the program. The CSFS also has assigned a full-time coordinator to its' staff.

In addition to the monitoring coordinators, seasonal staff will be assigned to gather pest/damage data on forest health plots. These crews will be trained in pest/damage assessment and will conduct "on-plot" and "off-plot" evaluations. FHM crews will assist FIA crews with tree crown and foliage measurements and bio-indicators of pollution-related damage. In addition, any causes of tree mortality will be evaluated.

In support of both "on-plot" and "off-plot" ground data gathering, FHM R-2 will obtain aerial imagery of the forest health plots in FY 92 in order to have a record of current condition of the forest. This imagery will serve as a baseline for forest condition that can be readily archived and retrieved and compared with subsequent imagery in the future. Stero-triplicate 9 x 9 color-infrared (CIR) photos (scale 1:6000) will be obtained for each forest health plot during the FY 92 field season. Video imagery may also be acquired as a comparison.

## LOGISTICAL PREPARATIONS

The logistics is being handled by the Intermountain Forest and Range Experiment Station (INT) FIA staff in Ogden, Utah and consists of:

- Establishment of the sample grid to maps and aerial photos.
- Acquisition of aerial photos and maps for the potential monitoring sites.
- Interpretation of plot sites from aerial photos.
- Selection of the set of forested field sites to visit on the ground.
- Equipment procurement.
- Contracting for transportation (jeeps, helicopters, pack animals).
- Determining land ownership.
- Obtaining access permission on private or restricted lands.
- Obtaining archeological permits, permits to traverse critical habitat, observe endangered plant and animal restrictions.
- Hire field crews (except FHM seasonals).
- Arrange for field crew lodging and meals.
- Arrange for training sites and instructors.
- Coordinate with federal resource managers (Forest Supervisors, District Rangers, Resource Officers, Park Rangers, etc.) access to sites under their management.
- Recon plot centers for as many sites as possible to reduce search time for field crews and flag route into plot.

## QUALITY CONTROL/QUALITY ASSURANCE

The Quality Control/Quality Assurance discipline developed by EPA for their EMAP effort will be adopted for the FHM/EMAP implementation in Colorado. Excellent quality control of data acquisition is assured thorough a very thorough set of data editing algorithms in the Portable Data Recorders (PDR's). All data collected on all aspects of the forest health monitoring program are entered through the PDR's and pass through edit algorithms that screen for illogical or otherwise erroneous entries. The PDR's also prevent the recorder from closing out a plot without completing all data items.

In addition, all data are transferred via electronic mail to headquarters each evening via dialup modems. Also, all samples taken in the field are handled in such a manner to guarantee a minimum amount of contamination to samples as they are collected. There are stringent processes for getting the samples (soil, foliar, lichens, tree cores, etc.) to the labs at EPA in a timely manner. A computerized bar-coding process is used to assure proper coding of all samples.

Finally, there is a disciplined schedule and format for evaluating the work of the field crews. Two people spend about half the summer in this type of Quality Control.

## FIELD METHODS GUIDES

The field manual of procedures for the general measurements collected on the plots is quite extensive, and will not be included as part of this plan. It is written and published as a separate document.

One important aspect of the field data collection process is the identification of damage and pests, etc. that contribute to forest health decline. At least two FHM R-2 specialists will be hired as part of each field crew to help identify these situations. These specialists will be able to assist with tree mortality estimates, which are an important component of the tables listed in Appendix B. The field methods guide for collecting the mortality data and pest/damage data are included in Appendix F.

## DATA ANALYSIS

Most analysis will be done by FS or EPA scientists. However, if cooperators are used for special studies, or have special expertise in certain areas of data acquisition and analysis, they will be employed. Most analysis will be directed at completing a core set of report tables, which is consistent across the entire United States. In addition, some State specific tables will be produced, depending on the desires of the users. A listing of tables is shown in Appendix B.

### Forest Service Role in Analysis

The FS has the responsibility for conducting all data analysis associated with forest mensurational aspects of forest health monitoring. Analyses of these forest mensurational and forest damage data will be done by FS scientists using appropriate statistical analysis and reporting methods.

### EPA Role in Analysis

The EPA has the responsibility for analyzing all soils data, tree foliar data, and similar chemical analyses. Likewise, analyses of these data samples will be done by EPA scientists using appropriate statistical analysis and reporting methods. Data analysis and

interpretation will be performed at various centers of expertise, depending on the discipline being evaluated for change. The goal is to have data processed and preliminary reports of results ready within 9 months after the data are collected. More detailed reports, and additional studies will be forthcoming for a period of years following the initial data evaluation.

Prior to final publication of the monitoring results, reports will be reviewed by both FS and EPA scientists. Other cooperators will be given the opportunity to review results if they are asked or request to be included in the review process.

It is anticipated that some preliminary reports will be published within one year of the completion of the field work, however, results from these data will necessarily be limited since only one-quarter of the field sites will be measured in the first year. The CSFS will have a major role in reviewing reports.

The INT FIA group will have the lead role in preparing these reports. Analysts will endeavor to identify any differences between FHM statistics and previous FIA reports. These differences will be explained if possible.

**IMPLEMENTATION SCHEDULE**

It is estimated that, given the indicator and measurement requirements and pilot study work loads for the crews in the summer of 1992, about 3 plots can be completed in a 5 day work-week by each crew. At that rate, over the 6 pay periods of summer training and work, the 40 plots will be completed about mid-August. A listing of the plots to be visited in 1992 is in Appendix D.

The current schedule of implementation calls for installing one-quarter of the total Colorado EMAP grid each year for four years. It is the intention of the NFHM Program to begin re-visiting at least some of the first year's established sites in the second year, and again in the third year, while adding sites from the second year's implementation. By the fourth year, all of the grid of plots will be installed, and a large percentage of those that were installed in the first three years will have been revisited, some on every occasion.

Decision on the frequency of re-visitation will be made before beginning the second year of implementation. This will, of course, be dependent on future budgets.

**FUNDING NEEDS (FHM R-2/CSFS)**

The funding needs for FHM R-2 and the CSFS the first year of implementation are estimated at about $238,000 to install 40 plots using two field crews. About $97,000 is for full-time coordinators for FHM R-2 and CSFS and seasonal staff. About $30,000 is required for per diem. About $10,000 is for vehicles. Nearly $13,500 is needed for field equipment purchase and $65,000 for aerial imagery and interpretation. A more detailed display of expenses is in Appendix C.

## INDICATORS OF FOREST HEALTH

A suite of indicators was selected for testing in the Eastern FHM/EMAP implementation and pilot studies during the summers of 1990 and 1991. A set of additional indicators was selected and pilot tested in the West during 1991. The suite of indicators tested, along with a list of variables measured or observed is summarized in Appendix E.

The suite of indicators generally encompasses the following general criteria:

- Forest Mensuration Indicators.
  - Tree Growth, Mortality, Age, etc.
  - Crown Evaluation (density, dieback, foliar transparency)
  - Foliar Evaluation (chemistry, needle density, needle age, etc.)
  - Dendrochronological Data (tree cores).
- Forest Ecosystem Damage
  - Tree damage --Signs and Symptoms (insect, disease, other)
  - Damage to Indicator Plants
- Biodiversity Indicators
  - Vegetation structure
  - Wildlife habitat
- Soils Characteristics
  - Physical
  - Chemical
  - Fertility/Productivity

There are several additional data items collected, such as the standard plot/site descriptors (elevation, slope, aspect, terrain, etc.), as well as the new variables being tested under the pilot study, such as Photosynthetic Active Radiation (PAR), root disease presence, tree height measurements, lichen characterization, and others.

In addition, numerous data are anticipated from ancillary sources, such as climatology, history of the ecosystem, remote sensing data, and etc.

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## APPENDIX A

## COLORADO FOREST HEALTH MONITORING PROGRAM SCHEDULE

| Activity | Duration | Month/Day | Accomplishment |
|---|---|---|---|
| NFHM meeting, Lakewood, CO | 3 d | 12/3-6/90 | Completed |
| NFHM meeting, Denver, CO | 2 d | 8/13-14/91 | Completed |
| Western pilot test, Durango, CO | 2 d | 8/28-29 | Completed |
| NFHM meeting, Ft. Collins, CO | 2 d | 9/4-5 | Completed |
| Write proposal for FHM funding | 10 d | 9/5-15 | Completed* |
| Review project proposal | 5 d | 9/15-20 | Completed |
| Submit proposal to WO | 1 d | 9/30 | Completed |
| Proposal accepted and funded | 1 d | 9/31 | Completed* |
| Western FHM meeting, Ogden, UT | 2 d | 12/5-6 | Completed |
| Write project overview brief | 5 d | 12/9-13 | Completed |
| Write PD for FHM Coordinator | 5 d | 12/9-13 | Completed |
| Write PD's for seasonals | 5 d | 12/16-20 | Completed |
| Western FHM meeting, San Francisco, CA | 3 d | 1/14-16/92 | Completed |
| Obtain approval for FTE's | 1 d | 3/3 | Completed* |
| Determine FHM plot locations (FIA) | 2 m | Feb-Mar | Completed* |
| Acquire vehicles/equipment | 4 m | Feb-May | Completed |
| Western Review FHM Program, Denver, CO | 1 d | 3/5 | Completed |
| Draft final FHM plan for Colorado | 5 d | 3/2-6 | Completed |
| Review draft plans | 2 m | 3/9-4/31 | Completed |
| Complete final plan | 1 w | 5/4-8 | Completed* |
| Assist NFS with recruitment of plant ID specialists | 3 w | 3/2-27 | Completed* |
| Select seasonals from applications | 4 w | 3/16-4/24 | Completed* |
| Western FHM meeting, Beaverton, OR | 3 d | 4/14-16 | Completed |
| Obtain orthophotos for aerial mission | 4 w | 4/27-5/22 | Completed* |
| FHM Coordinator reports for duty | 1 d | 5/18 | Completed* |
| Seasonals report for duty | 1 d | 5/18 | Completed* |
| Train seasonals in Utah/Colorado | 2 w | 6/1-6/12 | Completed* |
| Install FHM plots and collect data | 2.5 m | 6/15-8/7 | |
| Fly aerial photo mission | 2 w | 8/1-14 | |
| Debrief field crews | 2 d | 8/18-19 | |
| Interpret aerial photos | 1 m | Sep | |
| Analyze data | 2 m | Sep-Oct | |
| Prepare State report | 3 m | Nov-Jan | |
| Review FHM activities | 1 d | | |

* Designates a critical milestone.

## APPENDIX B

## LISTING OF ANALYSIS TABLE TITLES

Colorado Forest Health Monitoring

| | |
|---|---|
| Table 1 | Total area sampled by land use class and state. |
| Table 2 | Area of forest land sampled by forest type group and state. |
| Table 3 | Area of forest land sampled by forest type group and stand size class. |
| Table 4a | Relative percentages of live trees sampled by detailed species and tree size, all forest type groups. |
| Table 4b | Relative percentages of live trees sampled by detailed species and tree size, by forest type group. |
| Table 5a | Percentages of live trees 10 cm and larger by major species and crown class, all forest type groups. |
| Table 5b | Percentages of live trees 10 cm and larger by major species and crown class, by forest type group. |
| Table 6a | Percentages of overstory trees 10 cm and larger by major species and crown die-back class, all forest type groups. |
| Table 6b | Percentages of overstory trees 10 cm and larger by major species and crown die-back class, by forest type group. |
| Table 7 | Percentages of understory trees 10 cm and larger by major species and crown die-back class, all forest type groups. |
| Table 8a | Percentages of overstory trees 10 cm and larger by major species and foliar transparency class, all forest type groups. |
| Table 8b | Percentages of overstory trees 10 cm and larger by major species and foliar transparency class, by forest type group. |
| Table 9a | Percentages of understory trees 10 cm and larger by major species and foliar transparency class, all forest type groups. |
| Table 9b | Percentages of understory trees 10 cm and larger by major species and foliar transparency class, by forest type group. |

APPENDIX B continued

Table 10a Percentages of overstory trees 10 cm and larger by major species and crown ratio, all forest type groups.

Table 10b Percentages of overstory trees 10 cm and larger by major species and crown ratio, by forest type group.

Table 11a Percentages of understory trees 10 cm and larger by major species and crown ratio, all forest type groups.

Table 11b Percentages of understory trees 10 cm and larger by major species and crown ratio, by forest type group.

Table 12a Percentages of overstory trees 10 cm and larger by major species and crown density class, all forest type groups.

Table 12b Percentages of overstory trees 10 cm and larger by major species and crown density class, by forest type group.

Table 13 Percentages of understory trees 10 cm and larger by major species and crown density class, by forest type group.

Table 14 Percentage distribution of mortality trees, 10 cm and larger, by cause of death within major species, all forest type groups.

Table 15 Percentage distribution of mortality trees, 9.9 cm and smaller, by cause of death within major species, all forest type groups.

Table 16 Percentage distribution of damage signs and symptoms within major species, live trees, 10 cm and larger, all forest type groups.

Table 17 Percentage distribution of species impacted by damage signs and symptoms, live trees, 10 cm and larger, by forest type groups.

Table 18 Percentage of seedlings and saplings by major species and crown vigor class, all forest type groups.

Table 19 Percentage distribution of pollutants by foliage by tree species by forest type groups.

Table 20 Percentage distribution of pollutants by lichen species by forest type groups.

Table 21 Percentage occurrence of soil pollutants by forest type group and soils taxonomic class.

## APPENDIX C

## SUMMARY OF ANTICIPATED EXPENSES

The following is a listing of costs for Forest Health Management-R-2 and the Colorado State Forest Service portions of the program.

Forest Health Management (R-2)

| | |
|---|---|
| Personnel (1 FTE Coordinator, 5 seasonals) | $55,000 |
| Travel/Per diem | 23,000 |
| Vehicles (4 - 4x4's) | 10,000 |
| Supplies/Misc. | 11,500 |
| Aircraft Mission (Acquire photos, and interpretation) | 65,000 |
| Total | $165,000 |

Colorado State Forest Service

| | | |
|---|---|---|
| Personnel (1 FTE Coordinator, 2 seasonals) | | $41,947 |
| Fringe benefits | | 6,953 |
| Travel | 6,500 | |
| Supplies | | 2,080 |
| Indirect Charges | | 15,520 |
| Total | | $73,000 |

## APPENDIX D

## LISTING OF FHM PLOT LOCATIONS FOR 1992

| HEXAGON # | FOREST/DISTRICT/COUNTY | TOWNSHIP/RANGE/SECTION |
|---|---|---|
| | PLOTS WITHIN NATIONAL FORESTS | |
| 4010682 | Routt | 11N, 79W, S1 |
| 4010667 | Routt | 9N, 84W, S15 |
| 4010566 | Arapaho-Roosevelt | 8N, 74W (no section) |
| 3910567 | Arapaho-Roosevelt | 4S, 75W, S21 |
| 4010714 | White River | 1N, 89W, S30 |
| 3910643 | White River | 6S, 80W, S32 |
| 3910831 | White River | 8S, 95W, S31 |
| 3910543 | Pike | 7S, 70W, S29 |
| 3910715 | Gunnison | 12S, 91W, S1 |
| 3810678 | Gunnison | 15S, 86W, S3 |
| 3810684 | San Isabel | 12S, 81W, S23 |
| 3810715 | Uncompahgre | 44N, 7W, S14 |
| 3810615 | Rio Grande | 43N, 4E, S2 |
| 3710771 | Rio Grande | 41N, 2W, S27 |
| 3710655 | Rio Grande | 38N, 4E, S28 |
| 3710832 | San Juan | 36N, 12W, S28 |
| | PLOTS WITHIN BLM LANDS | |
| 3910778 | Craig | 3S, 94W, S6 |
| 4010815 | Craig | 1N, 99W, S8 |
| 3910855 | Grand Junction | 5S, 100W, S25 |
| 3810816 | Montrose | 45N, 16W, S32 |
| 3810731 | Montrose | 47N, 1.5W, S36 |
| | PLOTS WITHIN PRIVATE OWNERSHIP | |
| 4010542 | Larimer | 5N, 69W, S20 |
| 4010738 | Moffat | 4N, 94W, S20 |
| 4010627 | Routt | 3N, 84W, S8 |
| 3910754 | Garfield | 6S, 90W, S9 |
| 3910638 | Pitkin | 9S, 86W, S13 |
| 3810583 | Teller | 13S, 71W, S15 |
| 3810856 | Mesa | 50N, 16W, S15 |
| 3810755 | Montrose | 50N, 6W, S33 |
| 3810831 | Montrose | 47N, 11W, S8 |
| 3810427 | Pueblo | 22S, 67W, S11 |
| 3710468 | Huerfano | 27S, 67W, S32 |
| 3710856 | Montezuma | 39N, 17W, S23 |
| 3710731 | Archuleta | 35N, 2.5W, S1 |
| 3710428 | Las Animas | 33S, 68W, S15 |
| 3710716 | La Plata | 33N, 8W, S25 |
| 3710615 | Archuleta | 32N, 3E (no section) |

## APPENDIX E

## SUMMARY OF WESTERN U.S. INDICATORS AND DATA ITEMS FOR FOREST HEALTH MONITORING

SITE DESCRIPTIONS

Plot identification
- State (administration unit)
- County (administration unit)
- Plot number (identifier)
- Map Identification Code
- Universal Transvers Mercator Coordinates
- Photo Identification Code
- Photo year (year aerial photo was flown)
- Elevation
- Terrain position (i.e. floodplain, side slope, ridge-top)
- Date of visit (mm/dd/yy)

Plot description
- Land condition class
- Forest type (ecosystem)
- Greenness Index (NDVI) for AVHRR Satellite imagery
- Origin of stand/vegetation
- Size of stand/vegetation
- Past disturbance history
- Disturbance period
- Age of stand/vegetation (optional)
- Forest site data-(tree species, height, age)

Point description (subplot)
- History
- Slope
- Aspect
- Micro-relief
- Subplot center condition
- Slope correction (used in measuring from previous subplot)
- Site and Risk Classification Indices (i.e. Keen/Dunning).

TREE MENSURATION (list may be reduced for seedling and sapling trees)

- Tree diameter
- Radial growth (from coring or remeasurement)
- Age (from coring)
- Core element analysis
- Damage (presence of pathogens or insects, etc.)

- Tree mortality
- Condition class (describes veg./use condition in which tree exists)
- Regeneration
- Seed/cone production and viability
- History (history of tree establishment)
- Height growth (?? --in pilot test)
- Root disease evaluations (?? --in pilot test)
- Mycorrhizae root sampling (?? -in pilot test)

- Tree crown evaluation
  - Ratio (percent of the tree in crown)
  - Class (dominance of tree in stand)
  - Density
  - Dieback
  - Foliar transparency
  - Needle retention
  - Shape (optional--used for vegetation profile changes)
  - Diameter (optional--used for vegetation profile changes)
  - Foliar sampling (from tree climbers or shotgun extraction)
    - Chemistry (including nutrients and nutrient cycling)
    - Needle age
    - Needle position in growth flushes
    - Branch order (relative to physiological activity)
    - Branch vertical position in crown

GENERAL MENSURATION

- Micro-plot vegetation characterization and description
- Air pollution bioindicators (visual symptoms on trees and plants)
  - Ozone damage
  - Sulfur dioxide damage
  - Hydrogen fluoride damage
- Photosynthetic active radiation-PAR (?? under pilot test)
- Vegetation habitat structure (vegetation profile)
- Lichen occurrence and chemistry (?? under pilot test).

SOILS

- General processes:
  - Characterization and evaluation of:
    - Physical properties
    - Chemical properties, including toxins
    - Fertility/nutrient attributes
    - Productivity, in general

## APPENDIX F

## DAMAGE AND MORTALITY ASSESSMENT
## FHM METHODS GUIDE

DAMAGE SYMPTOMS AND SIGNS - OVERVIEW

Damage (DamageX) caused by diseases, insects, air pollution, and natural and man-made activities can affect the growth and development of the forests. Any of these agents, either singly or in combination, can cause significant declines in forest tree health. Identification of such agents can provide valuable information concerning the status of the forest condition and indicate possible causes of deviations from the expected norm. Symptoms and signs are recorded if, in the estimate of the observers, the damage could kill the tree, cause growth reduction of the tree, or provide entry points for other damaging agents.

Damage symptoms and signs are recorded on all live trees 1.0 inch DBH and larger on the microplot (1/300 acre, 6.8 ft. radius), and all live trees 5.0 inches DBH and larger on the subplot (1/24 acre, 24.0 ft. radius) (see Figure 3).

PROCEDURE

The tree will be observed from all sides and any identifiable symptoms and signs of damage noted. Up to three different types of damage and the location (LocatnX) of each can be recorded. If the symptoms and signs can be attributed to a probable causal agent (CauseX), then this also will be recorded.

Damage1 is the most significant damage to the tree in terms of impact on tree/forest health. It should be emphasized here that major growth impeding injury should be described and not the mere presence of a symptom and sign. To have more than one symptom and sign at this level should not occur frequently. We are trying to explain probable cause (CauseX) for growth impacts and tree mortality and not to conduct an inventory of everything present on a tree.

FHM Damage Coding -- In Colorado, tree damage will be assessed on all fader and mortality trees 5.0 inches and larger over the total hectare using the hectare plot layout procedures.
DAMAGE1 CODES:

Conditions which can occur in multiple (more than 1) locations:

| Code | Definition |
|---|---|
| 00 | None |
| 01 | Dead (describes part of a live tree) |
| 02 | Open wound (> 4 sq. in. inner wood exposed) |

| Code | Definition |
|---|---|
| 03 | Closed wound; healed, cankers; lesions (inner wood not exposed) |
| 04 | Small holes or pinholes (< 1/2 in. diam., e.g., bark beetle attack/emergence holes) |
| 05 | Broken |
| 06 | Removed; missing (other than defoliation by insects; branches or foliage) |
| 07 | Rotten branch stubs; excessive swelling at base of dead branches |
| 08 | Resinosis; bleeding |
| 09 | Deformed, twisted, curled (woody stems only) |
| 10 | Galls (abnormal swellings on mainstem or branches) |
| 11 | Imbedded foreign objects (nail, fence, etc.) |
| 12 | Corks and fruiting bodies |
| 13 | Fader tree (tree with live foliage, at least partially turning color in process of dying) |
| 14 | Other than described above (needs explanation in notes) |

Conditions which occur on trunk only:

| Code | Definition |
|---|---|
| 20 | Crook or sweep (severe enough to impede growth or affect survival) |
| 21 | Crack or seam |
| 22 | Swelling (greater than 1/2 diam of tree above the swelling) |
| 23 | Leaning (from partial windthrow or uprooting) |
| 24 | Abundance of epicormic branches or water sprouts on trunk or base |

Conditions which occur on branches only:

| Code | Definition |
|---|---|
| 40 | Excessive branching (indicator of past injury such as topkill) |
| 41 | Abundance of seeds or cones (may cause dieback) |
| 42 | Stunted, dwarfed (woody stems only, short internodes, chlorotic dwarfing) |

Conditions which occur on foliage only:

| Code | Definition |
|---|---|
| 60 | Defoliation (from insect feeding) |
| 61 | General discoloration (mixed colors; more than 30% of the crown with leaves having more than 50% of foliage affected; includes necrotic foliage) |

| Code | Definition |
|---|---|
| 62 | Pale green foliage (more than 30% of the crown with leaves having more than 50% of the foliage affected) |
| 63 | Yellow-green foliage (more than 30% of the crown with leaves having more than 50% of the foliage affected) |
| 64 | Leaves spotted (more than 30% of the crwn with foliage having spotted leaves) |
| 65 | Damaged leaves (more than 30% of the crown with foliage shredded, with holes, or otherwise mechanically damaged) |
| 66 | Distorted foliage (more than 30% of crown with wrinkled, shrivelled, galled, or otherwise distorted leaves) |
| 67 | Stunted foliage (more than 30% of crown with stunted or dwarfed foliage, less than 1/2 normal leaf size) |

LOCATION1 CODES:

This is the location (Locatn1) on the tree where the DAMAGE1 is found.

| Code | Definition |
|---|---|
| 1 | Crown stem (the main trunk or bole within the crown) |
| 2 | Upper bole (upper half of the trunk between roots and crown) |
| 3 | Lower bole (lower half of the trunk between roots and crown) |
| 4 | Roots (exposed) and stump (12 in. in height) |
| 5 | Whole trunk (includes 1-4) |
| 6 | Branches (woody stems other than the main stem) |
| 7 | Buds and shoots (the most recent year's growth) |
| 8 | Foliage |
| 9 | Whole crown (includes 6-8) |

PROBABLE CAUSE1 CODES:

This is a likely cause (Cause1) of DAMAGE1.

| Code | Definition |
|---|---|
| 100 | Insect |
| 200 | Disease |
| 300 | Fire |
| 400 | Animal |
| 500 | Weather |
| 600 | Plant competition/suppression |
| 700 | Logging and related; human damage |
| 800 | Unknown |

900 True Mistletoe
911 Dwarf mistletoe/severity rating
912 Dwarf mistletoe/severity rating
913 Dwarf mistletoe/severity rating
914 Dwarf mistletoe/severity rating
915 Dwarf mistletoe/severity rating
916 Dwarf mistletoe/severity rating
999 Other than described above; needs explanation in notes

Note: These codes are further expanded to genera and species where field identification is possible. See following list of specific pest codes for FHM coding for DAMAGE and MORTALITY.

DAMAGE2

This is the second most important damage (Damage2) relative to tree/forest health decline recorded for the tree. See DAMAGE1 for codes.

LOCATION2

This is the location (Locatn2) on the tree where DAMAGE2 is found. See LOCATION1 for codes.

PROBABLE CAUSE2

This is a likely cause (Cause2) of DAMAGE2. See PROBABLE CAUSE1 for codes.

DAMAGE3

This is the third most important damage (Damage3) relative to tree/forest health decline recorded for the tree. See DAMAGE1 for codes. The recording of a third damage (Damage3) should be used sparingly.

LOCATION3

This is the location (Locatn3) on the tree where the DAMAGE3 is found. See LOCATION1 for codes.

PROBABLE CAUSE3

This is a likely cause (Cause3) of DAMAGE3. See PROBABLE CAUSE1 for codes.

MORTALITY ASSESSMENT-OVERVIEW

Mortality caused by disease, insects, air pollution, and other natural or human activities can affect the structure and development of forests. Identification of such agents can provide valuable information concerning observed changes in forest condition and indicate possible causes of deviations from the expected norm. Combined with the damage information covered in the previous section, it will be possible to piece together the events that ultimately lead to the death of a tree.

Cause of death is recorded for all saplings 1.0 in. DBH and larger on the microplot, and all trees 5.0 in. DBH on the subplot that were recorded as live trees during the previous inventory. In addition, all mortality and fading trees 5.0 in. DBH and larger will be recorded on the full hectare plot by FHM crews. A "mortality tree" is one that has all needles or leaves dead, and has died within the last 5 years. Standard FIA criteria will be used for evaluating 5-year mortality. Use of these guidelines will only be necessary on the first visit to a FHM site, as new mortality will be obvious at the second visit.

Each one-hectare plot will be cruised by the FHM crew by walking the exterior boundary of the area. Borderline mortality trees will need to be checked with a tape. Any trees beyond the limiting distance (186.2 ft. radius), will not be included in the sample. All azimuth readings to the mortality trees will be from subplot 1 to the tree. All distances from the center of the subplot to the tree will be approximated to the nearest 3 feet.

The purpose of this procedure is to obtain a larger sample of mortality and fader trees than is available on the smaller 1/24 acre subplots.

Cause of death codes will be the same as listed for DAMAGEX.

**Specific pest codes for FHM coding for DAMAGE AND MORTALITY:**

| Code | Agent (Abbev) | Scientific name | Common name |
|---|---|---|---|
| **100** | **Insect - General** | | |
| **110** | **Bark beetles - General** | | |
| 111 | Dead | Dendroctonus adjunctus | Roundheaded pine beetle |
| 112 | Debr | Dendronctonus brevicomis | Western pine beetle |
| 113 | Depo | Dendroctonus ponderosae | Mountain pine beetle |
| 114 | Deps | Dendroctonus pseudotsugae | Douglas-fir beetle |
| 115 | Deru | Dendroctonus rufipennis | Spruce beetle |
| 116 | Deva | Dendroctonus valens | Red turpentine beetle |
| 117 | Deco | Dendroctonus confusus | Western balsam bark beetle |
| 118 | Ipsp | Ips sp. | Ips engraver beetle |
| 119 | Scve | Scolytus ventralis | Fir engraver |
| **120** | **Defoliators - General** | | |
| 121 | Chpi | Chionaspis pinifoliae | Pine needle scale |
| 122 | Chla | Choristoneura lambertiana | Sugar pine tortrix |
| 123 | Choc | Choristoneura occidentalis | Western spruce budworm |
| 124 | Cosp | Coleotechnites sp. | Leaf miners |
| 125 | Masp | Malacosoma sp. | Tent caterpillars |
| 126 | Maca | Malacosoma californicum | Western tent caterpillar |
| 127 | Nesp | Neodiprion sp. | Pine sawflies |
| 128 | Orps | Orgyia pseudotsugata | Douglas-fir tussock moth |
| 129 | Rear | Retinia arizonensis | Pinyon pitch nodule moth |
| **130** | **Chewing/Sucking Insects - General** | | |
| 131 | Grsp | Grasshopper sp. | Grasshoppers |
| 132 | Cisp | Cicadidae sp. | Cicadas |
| 133 | Cisp | Cicadellidae sp. | Leafhoppers |
| 134 | Ersp | Eriophyidae sp. | Eriophyid mites |
| 135 | Mova | Mordvilkoja vagabunda | Poplar vagabond aphid |
| 136 | Olun | Oligonychus ununquis | Spruce spider mite |
| 137-39 | Open | | |
| **140** | **Boring Insects - General** | | |
| 141 | Agsp | Agrilus sp. | Hardwood borer |
| 142 | Pite | Pissodes terminalis | Lodgepole terminal weevil |
| 143 | Pien | Pissodes engelmannii | Spruce terminal weevil |
| 144 | Rhsp | Rhyacionia sp. | Pine tip moth |
| 145-49 | Open | | |
| **150** | **Seed/Cone/Flower/Shoot Insects - General** | | |
| 151 | Chsp | Choristoneura sp. | Budworms |
| 152 | Disp | Dioryctria sp. | Dioryctria moths and coneworms |
| 153-59 | Open | | |
| **160** | **Gallmaker Insects - General** | | |
| 161 | Pine | | Pinyon needle galls |
| 162 | Adco | Adelges cooleyi | Cooley spruce gall aphid |
| 163-69 | Open | | |

**Specific pest codes for FHM coding for DAMAGE AND MORTALITY** continued

| | | | |
|---|---|---|---|
| **200** | **Disease - General** | | |
| **210** | **Root/Butt Diseases - General** | | |
| 211 | Amsp | Armillaria sp. | Armillaria root disease |
| 212 | Hean | Heterobasidion annosum | Annosus root disease |
| 213 | Lewa | Leptographium wagenerii | Black stain root disease |
| 214 | Into | Inonotus tomentosus | Tomentosus root disease |
| 215-19 | Open | | |
| **220** | **Stem Diseases - General** | | |
| 221 | Cesi | Cenangium singulare | Sooty bark canker |
| 222 | Cefi | Ceratocystis fimbriata | Ceratocystis canker |
| 223 | Crco | Cronartium comandrae | Comandra blister rust |
| 224 | Crri | Cronartium ribicola | White pine blister rust |
| 225 | Crpo | Cryptosphaeria populina | Cryptosphaeria canker |
| 226 | Cysp | Cytospora sp. | Cytospora canker |
| 227 | Hyma | Hypoxylon mammatum | Hypoxylon canker |
| 228 | Peha | Peridermium harknessii | Western gall rust |
| 229 | Open | | |
| **230** | **Parasitic/Epiphytic Plants - General** | | |
| 231 | Aram | Arceuthobium americanum | Lodgepole pine dwarf mistletoe |
| 232 | Arcy | Arceuthobium cyanocarpum | Limber pine dwarf mistletoe |
| 233 | Ardi | Arceuthobium divaricatum | Pinyon dwarf mistletoe |
| 234 | Ardo | Arceuthobium douglasii | Douglas-fir dwarf mistletoe |
| 235 | Arva | Arceuthobium vaginatum/ cryptopodum | Southwestern dwarf mistletoe |
| 236 | Phju | Phorodendron juniperium | Rocky Mountain juniper mistletoe |
| 237-39 | Open | | |
| **240** | **Decline Complexes/Dieback/Wilts - General** | | |
| 241 | Buxy | Bursaphelenchus xylophilus | Pinewood nematode |
| 242 | Cefa | Ceratocystis fagacearum | Oak wilt |
| 243 | Ceul | Ceratocystis ulmi | Dutch elm disease |
| 244-49 | Open | | |
| **250** | **Foliage Diseases - General** | | |
| 251 | Ciwh | Ciborinia whetzelii | Ink spot of aspen |
| 252 | Elde | Elytroderma deformans | Elytroderma needlecast |
| 253 | Losp | Lophoderium sp. | Lodgepole needlecast |
| 254 | Mapo | Marssonina populi | Marssonina leaf blight |
| 255 | Neco | Neopeckia coulteri | Brown felt blight |
| 256 | Pora | Pollaccia radiosa | Shepherds crook |
| 257 | Spsa | Sphaeropsis sapinea | Diplodia blight |
| 258 | Vema | Venturia macularis | Poplar shoot blight |
| 259 | Open | | |

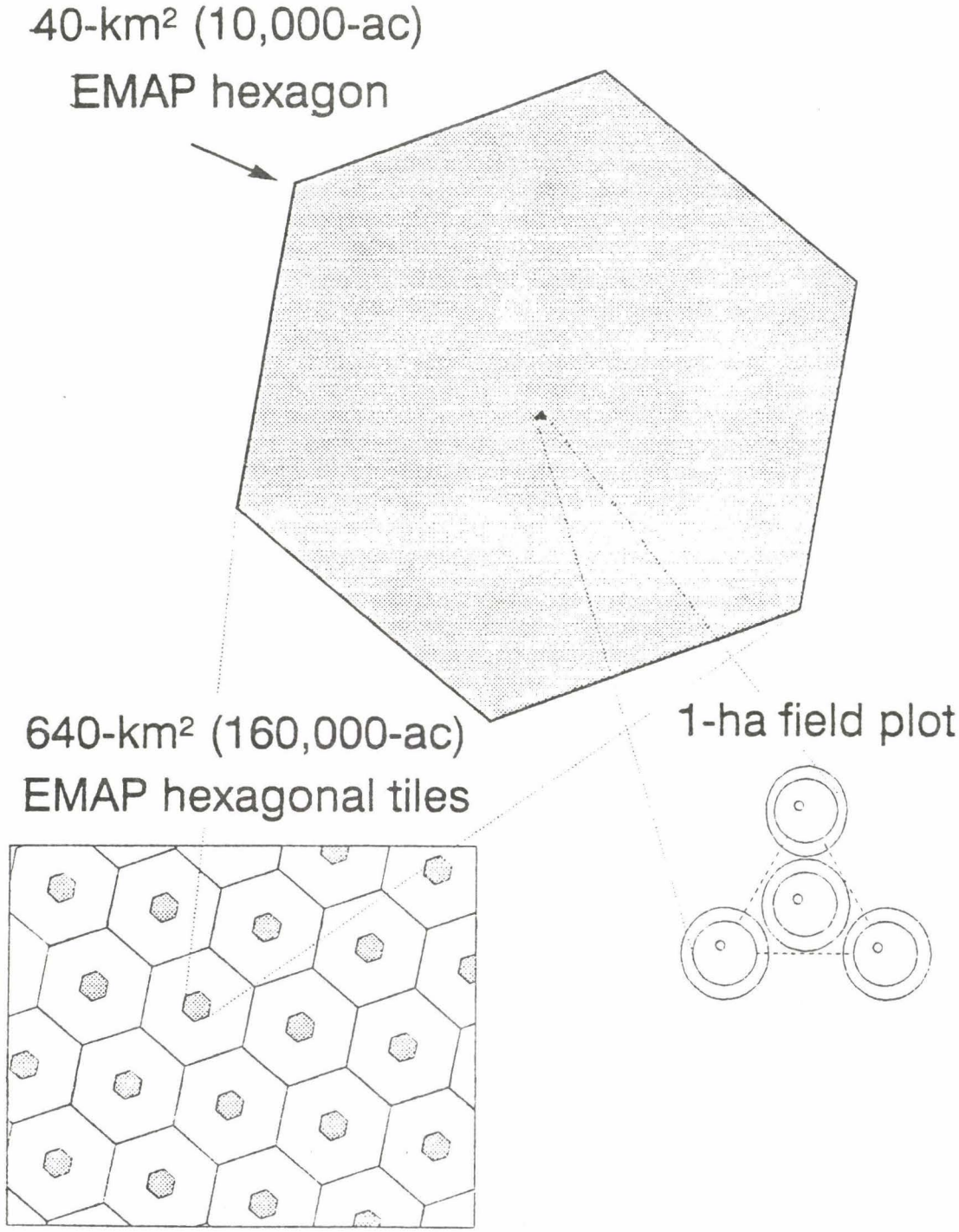
**Specific pest codes for FHM coding for DAMAGE AND MORTALITY** continued

| | | | |
|---|---|---|---|
| 260 | **Broom Rusts/Limb Rusts - General** | | |
| 261 | Char | Chrysomyxa arctostaphyli | Spruce broom rust |
| 262 | Meca | Melampsorella carophyllacearum | Fir broom rust |
| 263 | Pefi | Peridermium filamentosum | Limb rust |
| 270 | **Decays/Rots - General** | | |
| 271 | Ecti | Echinodontium tinctorium | Rust-red stringy rot |
| 272 | Fopi | Fomitopsis pinicola | Red belt fungus |
| 273 | Gaap | Ganoderma applanatum | White mottled rot |
| 274 | Pefr | Pereniporia fraxinophila | Ash heart rot |
| 275 | Phpi | Phellinus pini | Red ring rot |
| 276 | Phtr | Phellinus tremulae | White trunk rot |
| 277-79 | Open | | |
| 300 | **Fire - General** | | |
| 400 | **Animal - General** | | |
| 410 | Porcupines | | |
| 411 | Rodent feeding | | |
| 412 | Squirrels | | |
| 500 | **Weather - General** | | |
| 600 | **Plant competition/suppression - General** | | |
| 700 | **Logging and related; human damage - General** | | |
| 800 | **Unknown** | | |
| 900 | **True Mistletoe** | | |
| 911 | **Dwarf mistletoe/severity rating** | | |
| 912 | **Dwarf mistletoe/severity rating** | | |
| 913 | **Dwarf mistletoe/severity rating** | | |
| 914 | **Dwarf mistletoe/severity rating** | | |
| 915 | **Dwarf mistletoe/severity rating** | | |
| 916 | **Dwarf mistletoe/severity rating** | | |
| 999 | **Other than described above; needs explanation in notes** | | |

*** Make a best effort at this but do not guess. If the cause of death in uncertain, use code 800. If the cause of death in not on the list, use code 999 and explain in the notes.**

Figure 1. Map of Colorado with hexagon locations.

Figure 2. Current FHM/EMAP field plot design



Distance between points is 120'

Azimuth 1-2 360°
Azimuth 1-3 120°
Azimuth 1-4 240°

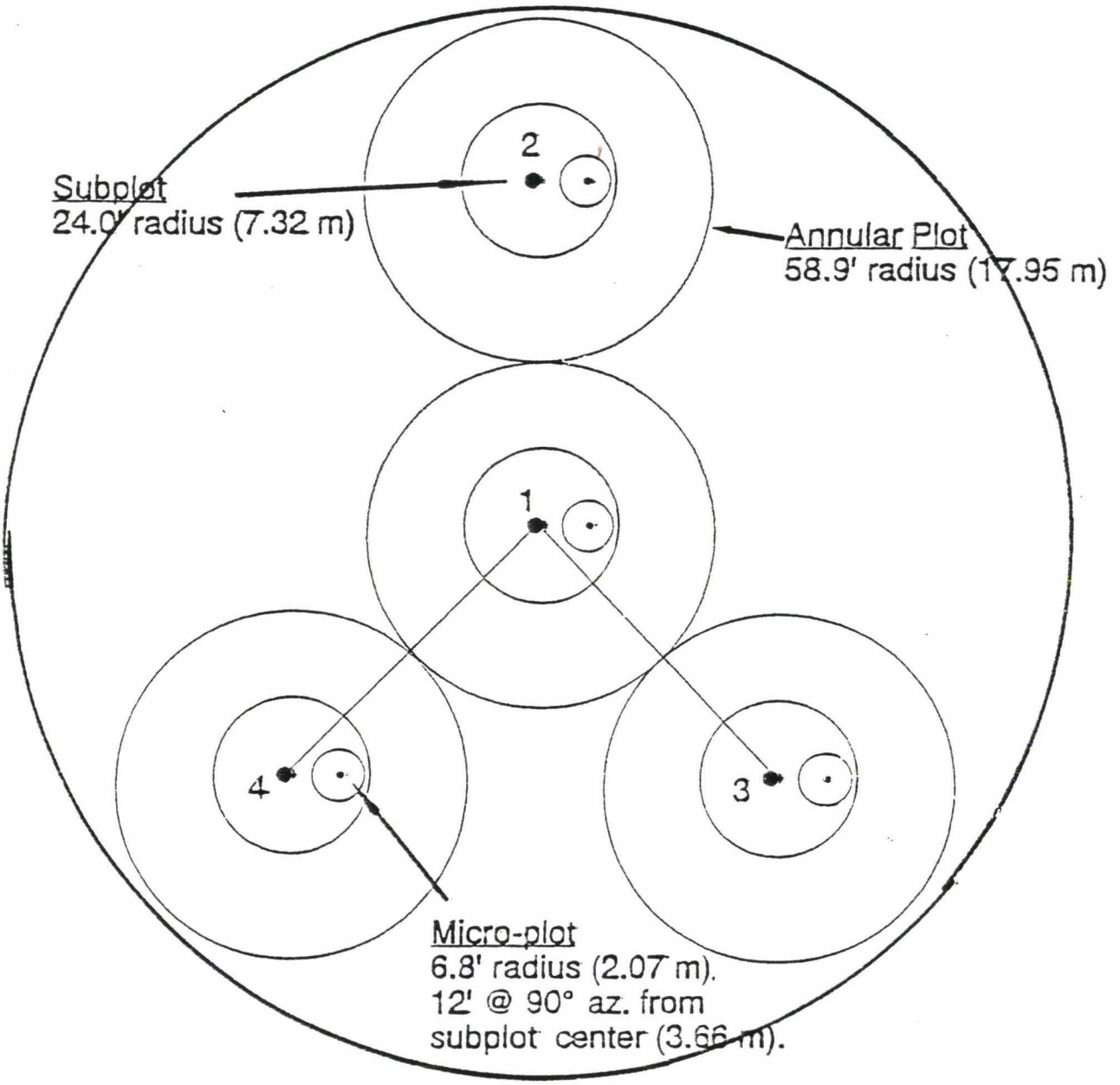



Figure 3. National FHM plot layout is designed around 4-points (subplot centers).

PLOT FORM
FHM WESTERN MORTALITY, FULL HECTARE PLOT
(Radius 56.4 Meters or 186.2 Feet)



Times: Start _ _ hr. _ _ min.; Stop _ _ hr. _ _ min.

STATE _ _ COUNTY _ _ _ PLOT # _ _ _ _ _ _ _ TALLY _ _ _

BOUNDARY: PLOT TYPE (MORTALITY) 3

CONDITION 1= LU _ _; FT _ _ _ _; SO _; SSC _; PD _ _
CONDITION 2= LU _ _; FT _ _ _ _; SO _; SSC _; PD _ _
Hectare boundary to center point (Boundary 1)
Left Azimuth _ _ _ Right Azimuth _ _ _
Corner Azimuth _ _ _ Corner Distance _ _ _

CONDITION 3= LU _ _; FT _ _ _ _; SO _; SSC _; PD _ _
Hectare boundary to center point (Boundary 2)
Left Azimuth _ _ _ Right Azimuth _ _ _
Corner Azimuth _ _ _ Corner Distance _ _ _

CONDITION 4= LU _ _; FT _ _ _ _; SO _; SSC _; PD _ _
Hectare boundary to center point (Boundary 3)
Left Azimuth _ _ _ Right Azimuth _ _ _
Corner Azimuth _ _ _ Corner Distance _ _ _

| FADER/N | COND. CLASS | TREE NUMBER | TREE AZIMUTH TO PT. | MORTALITY SPECIES | DBH | CAUSE OF DEATH | CAUSE OF DEATH | CROWN CLASS | HEIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | | |
| X | X | XXX | XXX | XX | XXX | XXXX | XXX | XXX | X | XXX |
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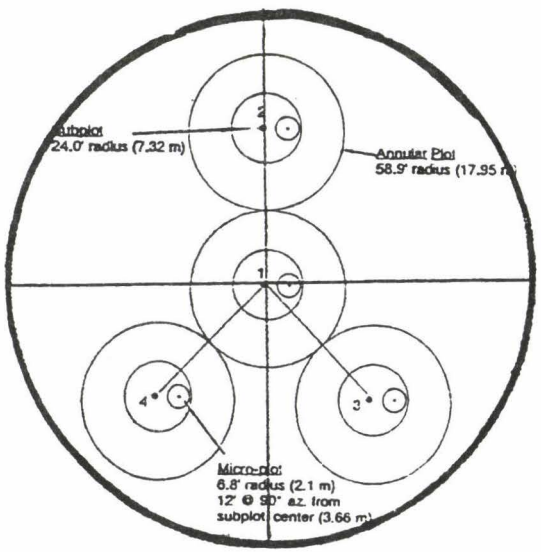

PLOT FORM
FHM WESTERN MORTALITY, FULL HECTARE PLOT
(Radius 56.4 Meters or 186.2 Feet)



| FADER Y/N | COND. CLASS | TREE NUMBER | NEAREST PT. | AZIMUTH TO PT. | MORTALITY YR. | SPECIES | DBH | CAUSE OF DTH. 1 | CAUSE OF DTH. 2 | CROWN CLASS | HEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| X | X | XXX | X | XXX | XX | XXX | XXXX | XXX | XXX | X | XXX |
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